Chapter 3

Affected Environment

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3.1 INTRODUCTION

The Affected Environment was described in the 1997 Draft EIS, Chapter III. This chapter updates the existing resource conditions at or near GSM that would be affected by the pit reclamation alternatives. Resources that would not be affected by the alternatives evaluated are not discussed in detail. These resources are vegetation, aquatics, fisheries, noise, and air quality.

3.2 GEOLOGY AND GEOTECHNICAL

The 1997 Draft EIS, Section III.A.2, included a detailed discussion of the regional and local geology of the mine site, as well as geotechnical aspects of block movement within the Tertiary and Quaternary sediments east of the pit. The SEIS includes a short summary of regional geology, focusing on the geology of the pit area and portions of the East Waste Rock Dump Complex overlying Rattlesnake Gulch. This provides a basis for understanding the geological influence on potential flow paths of contaminated groundwater from these facilities. The geotechnical portion of the SEIS updates long-term pit highwall stability analyses.

What has changed in Chapter 3 since the DSEIS?

Chapter 3 describes the affected area around GSM. Based on additional data and public comments, the following changes have been made:

- The GSM 2004 Annual Report was used to update all figures. The GSM 2006 Annual Report was used to update some acreage numbers.
- The net pit inflow rate was changed from 16 gpm to between 25 and 27 gpm based on the updated water balance for the No Action Alternative (No Pit Pond Alternative.
- The Jefferson River alluvium was described in more detail.
- Information on the 2004 earthquake and its effects on the area are provided.
- Additional tasks completed to provide technical information for the SEIS on the Water Resources and Geochemistry were listed.
- Additional information on springs was provided.
- Table 3-1 was updated to include Sunlight and Arkose Valley springs information.
- Information on the groundwater divide on the east side of the pit was added.
- Additional wildlife species found or that may be found near the area were listed.
- All text, figures and tables were revised from data provided by GSM and various consultants.
- Text was corrected based on references.

The geology of the open pit is the same as that discussed in the 1997 Draft EIS, even though GSM proposes to mine to the 4,525-foot elevation. The Water Resources and Geochemistry Section 3.3 will discuss any changes in the geology of the pit highwall and backfill that might affect water quality from that analyzed in the 1997 Draft EIS, Section III.B.

3.2.1 Geology

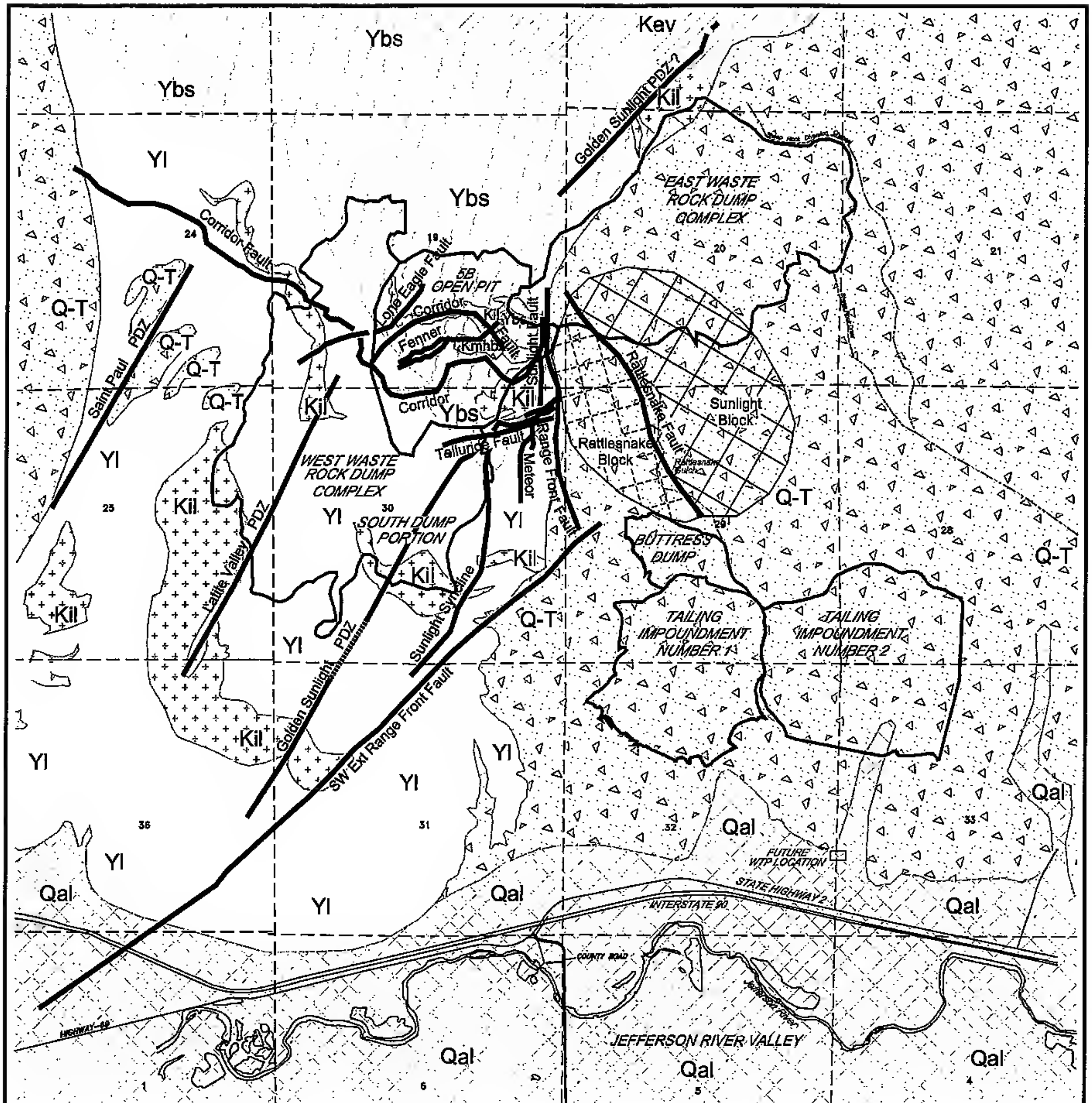
3.2.1.1 Regional Geology and Geologic Structures

GSM is located on the southern flank of Bull Mountain. Figure 3-1 shows a general map of the surficial geology in the vicinity of the mine. Bull Mountain is composed of ancient sedimentary rock that was deposited in a shallow sea during late Precambrian time approximately 1.4 billion years ago. The Precambrian rock types in the vicinity of the mine include sandstone, siltstone, and shale. These rock units are part of the Precambrian Belt Supergroup, and also have been referred to as the LaHood, Greyson, and Newland formations, and the Bull Mountain Shale.

A period of mountain building or tectonic activity known as the Laramide Orogeny occurred approximately 70 to 85 million years ago during the Cretaceous. In the vicinity of the mine, regional compression of the earth's crust created folded blocks of rock followed by extension that resulted in high-angle (near vertical) faults. Precambrian rocks were penetrated by igneous intrusions and overlain by volcanic materials during this period. Cretaceous intrusive rocks in the vicinity of the mine include latite porphyry and numerous smaller lamprophyre dikes.

After the Laramide Orogeny, the landscape was relatively stable. During this time, residual (in-place) weathering of the rock surface was the dominant geologic process. During the Tertiary Period, tectonic activity continued in the form of relaxation of compression, or extension of the earth's crust. This formed the shallow basin east of Bull Mountain, which filled with Tertiary and Quaternary sediments. Part of this sediment-filled valley is now the site of the facility buildings, tailings impoundments, and the East Waste Rock Dump Complex. The geology of the sediments that underlie these facilities, particularly as it influences groundwater flow paths, is the focus of discussion in the following section. Local volcanic activity also is evident by the presence of Eocene (44-million-year-old) basalt, which is exposed near Tailings Impoundment No. 1.

The Precambrian sedimentary rocks in the vicinity of the mine are hydrothermally altered and contain sulfide minerals. When these sulfide minerals are exposed to water and air, they can produce metal-bearing, acidic iron sulfate solutions. These solutions are ARD.



LEGEND

	Qal	Quaternary Alluvial Deposits
	Q-T	Quaternary and Tertiary Deposits
	Kil	Crataceous Latite
	Kev	Cretaceous Elkhorn Volcanics
	Kmbx	Cretaceous Mineral Hill Breccia
	Ybs	Precambrian Bull Mountain Shale
	Yl	Precambrian LaHood Formation
		Fault
PDZ		Principal Deformation Zone

Source: 1997 Draft EIS (Map III-1), Golder
1995 (Fig. 4) Chadwick (1996)
1998 MBMG Website Geology Maps

0 1500 3000
Scale in Feet

GENERALIZED SURFACE GEOLOGY

Figure 3-1rev-SurfaceGeology.dwg Rev2/2006

FIGURE 3-1

Pyrite is by far the most abundant sulfide mineral. The average abundance of pyrite in GSM ore is between 3 and 5 percent. The average abundance of pyrite in the waste rock is between 0.5 and 2 percent. Concentrations of up to 20 percent occur, but are not typical. The relatively fine texture of this pyrite enhances the surface area available for ARD generation. Other metallic minerals occur in minor amounts and vary in accordance with zoning in the ore body. Water treatment constituents of concern in ARD include aluminum, arsenic, cadmium, copper, manganese, nickel, pH, sulfate, and zinc. With the exception of aluminum, the other metals are predominantly associated with sulfide complexes and oxides.

3.2.1.2 Bull Mountain Geology and Geologic Structures

The open pit is centered on a breccia pipe in the Precambrian host rocks. The pit cuts through and is bounded by a highly complex series of east and northeast trending high-angle faults (Foster and Chadwick, 1990; Foster, et al., 1993; Foster and Smith, 1995). The Range Front Fault is a major north-south high-angle slip fault that separates the Precambrian and Cretaceous rocks of the upland from the late Tertiary valley fill sediments. The Corridor Fault is a lens-shaped zone up to several hundred feet thick of low-angle faulting that dips approximately 16 degrees to the northeast (Hydrometrics, 1995). The major geologic structures in the vicinity of the pit are shown in Figure 3-2.

The breccia pipe contains disseminated gold-bearing sulfide mineralization that extends more than 100 feet into wallrock in silicified fractures. The pipe is an irregular 700-foot-diameter oval, which plunges 35 degrees to the west-southwest. Individual fragments in the breccia range from less than 1 inch to greater than 30 feet in size and consist of all local rock types except for the late intruding lamprophyre dikes. A low-grade porphyry molybdenum system is located in and adjacent to the mine, as is a zone of massive sulfides in Precambrian rocks. Alteration consists of pyritization, silicification, and decarbonization with an alteration mineral assemblage containing silica, pyrite, barite, sericite, chalcopyrite, galena, sphalerite, and molybdenite. Gold occurs as disseminated particles associated with pyrite and minor telluride minerals in the breccia matrix and surrounding rock. Superimposed across the breccia pipe and into the surrounding highwall rock are northeast trending gold-quartz veins that may contain pyrite, galena, sphalerite, and barite.

LEGEND

PDZ Principal Deformation Zone

Fault

NOTE: Refer to Figure 3-5 Spring and Monitoring Well Locations for complete location of all wells.

0 1200 2400
Scale in Feet

Figure 3-2 geostructures.dwg

MAJOR BEDROCK GEOLOGIC STRUCTURES IN THE VICINITY OF THE PIT

FIGURE 3-2

3.2.1.3 Tertiary/Quaternary Geology and Geologic Structures

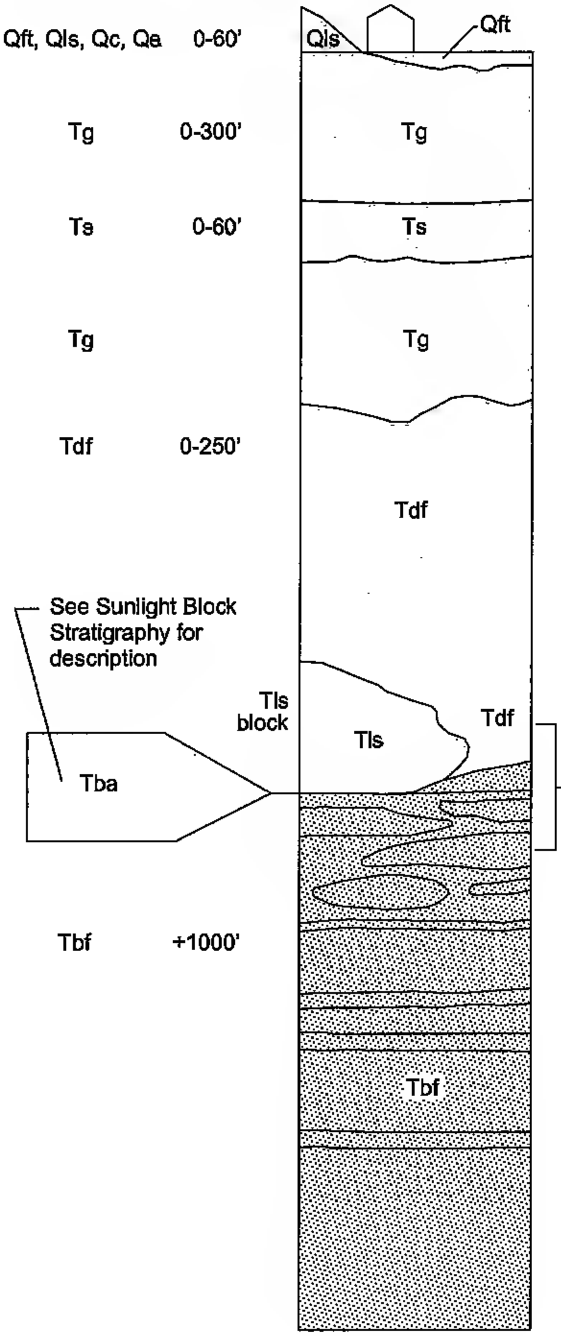
The area east of Bull Mountain contains valley fill Tertiary Bozeman Group sediments up to 1,500 feet thick (Hanneman, 1989). Figures 3-3 and 3-4 show stratigraphic sections from two locations east of Bull Mountain. These rocks and sediments have diverse lithologies, including low permeability clays, moderate permeability sandstone and conglomerate, and carbonate-bearing shales and limestones (1997 Draft EIS, Chapter III, Section A).

The Bozeman Group in the vicinity of the mine has been recognized as having a lower fluvial (stream deposits) facies (Tbf) and alluvial facies (Tba) (Figure 3-3). The fluvial facies generally consists of interbedded medium to high plastic clays and silts, sands and clayey sands. The fluvial facies contains unconsolidated channel sand interlayers, but the bulk of the unit consists of clays, which are interpreted as overbank deposits, exhibiting good lateral continuity (Golder, 1995a). The alluvial facies commonly contains less than 20 percent clay and consists of light brown, lightly calcareous, silty sands and gravels.

Late Tertiary mass-wasting deposits, consisting of landslide (Tls) and debris flow deposits (Tdf), overlie the Bozeman Group sediments unconformably along the east front of Bull Mountain. The mass-wasting deposits are generally confined to the Rattlesnake Block (Golder, 1995a) (Figure 3-3). The debris flow deposits are described as consisting of sandy and silty gravel that is fine to coarse and subrounded to angular, with cobbles and boulders. The debris flow deposits are up to 250 feet thick, massive to bedded, and unconsolidated to well cemented with iron oxide. Associated landslide deposits are composed of more or less intact blocks of latite and other pre-Tertiary bedrock blocks that may be up to 1,500 feet long and 200 feet thick.

SYMBOL	THICKNESS	DESCRIPTION
Qft, Qls, Qc, Qa	0-60'	Quaternary Sediments - fan terrace gravels (Qft), landslide (Qls), colluvium (Qc), and alluvial (Qa) deposits
Tg	0-300'	Tertiary (?) gravels (Tg); unconsolidated, anguler gravels of local derivation; grain supported with more or less sand - silt - clay matrix
Ts	0-60'	Tertiary (?) Sand (Ts); lacustrine beach sand; sheet-like bodies with basin-margin distribution. Well rounded med.-coarse grained quartz-feldspar-biotite sand. Frosted quartz grains, heavy mineral laminae; clean to silty and/or gravelly; unconsolidated.
Tg		
Tdf	0-250'	Tertiary debris flow and landslide deposits (Tdf/Tls) Clay-matrix supported sand to boulder size angular clasts. Massive to well bedded. Semi-consolidated to locally well-cemented with iron oxide. Landslide blocks up to 1500 feet in length, >200' thick.
Tbf	+1000'	Tertiary Bozeman Group - Fluvial Facies (Tbf) Unconsolidated, subrounded channel sand interbedded with overbank muds containing >50% clay. Granitic (distal) source terrain; occasional angular heterolithic interbeds of local provenance, especially near basin margins. The upper 200-300' is sandy; lenticular bodies of sand are common and may be >10 feet thick with over 100 feet of lateral continuity. Thin interbeds of volcanic ash.

GRAPHIC COLUMN



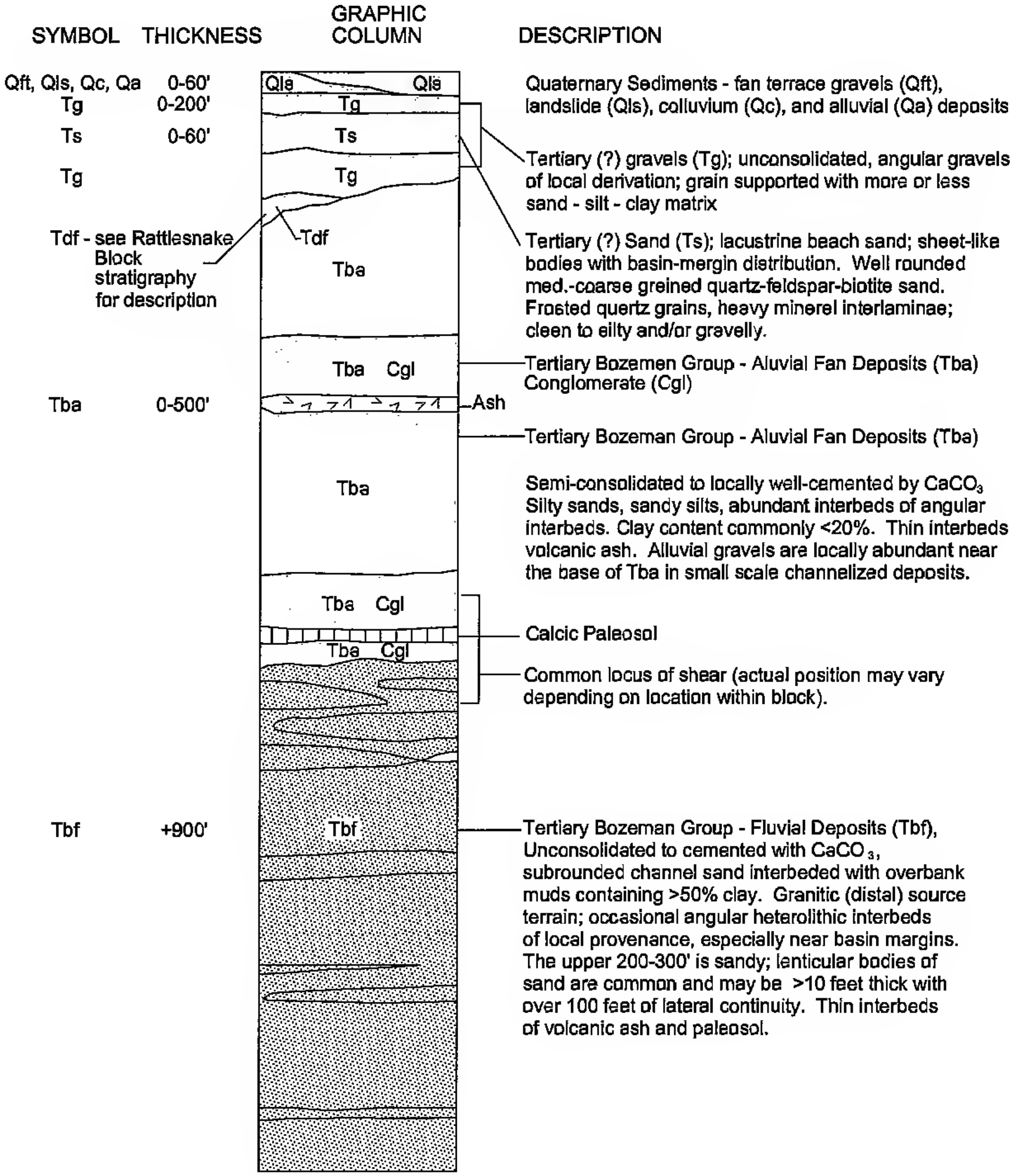
Common locus of shear (actual position may vary depending on location within block).
Shear is related to Rattlesnake Block movement.

GEOLOGY: T.H. CHADWICK
SOURCE: GOLDER, 1995a

TYPICAL STRATIGRAPHIC COLUMN FOR RATTLESNAKE BLOCK

FIGURE 3-3

Figure 3-3 column.dwg



GEOLOGY: T.H. CHADWICK
SOURCE: GOLDER, 1995a

TYPICAL
STRATIGRAPHIC COLUMN
FOR SUNLIGHT BLOCK

Figure 3-4 column.dwg

FIGURE 3-4

Alluvial fan gravels (Tg) and intercalated lacustrine sands (Ts) unconformably overlie the landslide-debris flow complex, with a thickness of as much as 360 feet. Disconformably overlying the Tertiary gravels and sands is a variety of thin Quaternary cover, including fan-terrace gravels, landslide, colluvial and alluvial deposits (Golder, 1995a) (Figure 3-3).

The Jefferson River alluvium is a stream deposit consisting of unconsolidated, permeable alluvium of the river floodplain and the adjacent gravelly terrace deposits (Spectrum Engineering and Gallagher, 2004). This unit follows the flow direction of the Jefferson River (Figure 3-1). At least one of the alluvial terraces is buried by 40 to 80 feet of more recent colluvium and alluvial deposits. It is likely the upper terraces grade into the recent alluvium of the Jefferson River system and are hydrologically connected to some degree. The alluvial deposits consist of unconsolidated gravel, sand, and finer-grained overbank deposits. The well-rounded gravel fraction includes quartzites and volcanics from up-river regions. Angular silicified siltstones and latite appear to be derived from the mine area. Much of the gravel is iron stained. Fragments of ferricrete are present from the Tertiary debris flow deposits. The six borings in the Jefferson River alluvium were distributed both up gradient and down gradient of the Tertiary debris flow deposits. Rock types associated with the mine area were seen in greater abundance in samples from downgradient borings. Samples from the unsaturated portion of the Jefferson River alluvium were calcareous and effervesced in hydrochloric acid, while samples from the saturated portion were non-calcareous and did not effervesce (Spectrum Engineering and Gallagher, 2004).

The Bozeman Group sediments to the east of the pit were the subject of a detailed geotechnical investigation related to block movements that were observed in the mid-1990s (Golder, 1995a). A detailed discussion of the block movements was provided in the 1997 Draft EIS, Chapter III, Section A. Two blocks were identified within the Tertiary sediments that are generally delineated as follows:

- The Rattlesnake Block lies between the Range Front Fault to the west and the Rattlesnake Fault to the east (see Figure 3-3 for stratigraphic section and Figure 3-1 for plan view).
- The Sunlight Block is situated between the Rattlesnake Fault to the west and Midas Draw to the east (see Figure 3-4 for stratigraphic section and Figure 3-1 for plan view).

3.2.1.4 East Waste Rock Dump Complex Geology and Geologic Structures

The East Waste Rock Dump Complex geology was described in detail in the 1997 Draft EIS, Chapter III, Section A and is summarized below. The East Waste Rock Dump Complex lies east of the pit and is located primarily on Tertiary gravels (Tg) and Bozeman Group sediments (Tba) (Figure 3-1). Thirteen percent of the dump complex lies over the Rattlesnake Gulch drainage and could contribute water to groundwater leaving the pit (Figure 3-7).

Bedrock is present below the dump complex at depths ranging from 0 to over 500 feet and is exposed at the surface at elevations above 5,050 feet. Bedrock in this area is composed predominantly of sedimentary rocks (sandstones, limestones, and shales) of Precambrian to Devonian age. The upper bedrock surface is highly weathered and altered to clay in some places. The sedimentary bedrock has been fractured, faulted, and folded, resulting in local variations in bedding orientation. The prevailing strikes of principal faults are north-northeasterly, and their dips are about 60 degrees to the east.

The East Waste Rock Dump Complex site is situated near the northern margin of the valley-fill deposits, with the bedrock surface generally deepening and widening towards the south. Immediately overlying the bedrock surface under much of the East Waste Rock Dump Complex area is a thin layer (0 to 40 feet) of Tertiary gravels, sands, and clays (Tcgl) (also known as the Red Hill Conglomerate) (Figure 3-4). This unit is highly variable in thickness and composition (1997 Draft EIS, Chapter III, Section III.A.2.d).

Bozeman Group sediments that underlie the footprint of the East Waste Rock Dump Complex consist of a thin to moderately thick (10 to 100 feet) bed of the silty alluvial fan facies (Tba), underlain by interbedded Tba and the more clayey fluvial facies (Tbf). Substantial layers of gravel and gravel/clay interbeds also are present within the Tbf/Tba unit. These gravelly layers are interpreted as Tertiary debris flow deposits that were shed off the steep mountain fronts in mass wasting events, as indicated on Figures 3-3 and 3-4. Alluvial fan sediments occur where mountain streams exit onto valley plains or where the stream gradient suddenly decreases. These deposits occur adjacent to the mountain front up to a maximum elevation of approximately 5,200 feet. Fluvial sediments deposited in the valleys by flowing streams are predominant below 4,900 feet in the mine area. The relationship between these deposits is often complex and the deposits are frequently interbedded (1997 Draft EIS, Chapter III, Section III.A.2.d).

3.2.1.5 Ferricrete Deposits

Ferricrete was not discussed in detail in the 1997 Draft EIS. Ferricrete is a term used to describe iron oxide/hydroxide precipitates that are associated with ARD (Taylor, 1997). Ferricrete is a common occurrence both on the surface and at depth at GSM. The importance of ferricrete with respect to the SEIS is that it provides an indication of pre-mining and modern ARD production at the site, and it provides an indication of the geochemical conditions of potential pit groundwater flow paths, in particular the neutralization capacity of the sediments along a given potential groundwater flow path.

Ferricrete deposits can be modern, indicating recent or ongoing ARD production, or ancient, indicating prehistoric production of acidic discharge. Taylor (1997) performed a detailed study of the occurrence of ferricrete at or near the surface at GSM and concluded that ferricrete deposition has been an ongoing process, dating back some 11,000 years. Ferricrete deposits have been documented in association with many of the springs located east and south of the GSM pit (Gallagher, 2003a).

A summary of the documented occurrence of ferricrete at GSM was prepared (HSI, 2003). The distribution of ferricrete on the surface is associated mainly with spring discharge emanating from bedrock to the south of the pit. Drill logs presented in Gallagher (2003a) indicate ferricrete is widely distributed in the debris flow deposits between the east flank of Bull Mountain and Rattlesnake Gulch (HSI, 2003). Historic ferricrete deposits do not appear to occur to the east of Rattlesnake Gulch. However, modern ferricrete is likely being created within the East Waste Rock Dump Complex (Taylor, 1997).

Ferricrete deposits have also been documented at depth along the eastern flank of Bull Mountain in monitoring wells, including PW-8, PW-12, PW-47, PW-63 and PW-64 (Figure 3-5), as well as in a gold-bearing hematite deposit that extends down the Rattlesnake Gulch drainage from just east of the pit down to Rattlesnake Spring. These deposits may be indicative of ancient surficial ferricrete deposits that were formed due to ARD emanating from the mineralized bedrock to the west, or they may have resulted from mass-wasting transport of mineralized Tertiary debris flow and landslide rock onto the east flank of Bull Mountain (URS, 2001).

3.2.2 Geotechnical

3.2.2.1 Ground Movements

Ground movements in the mine area are categorized according to three distinct mechanisms of instability:

- Sliding of materials off Bull Mountain on steep, near-surface shear planes;
- Relatively slow movement of massive blocks of valley-fill sediments along deep, low-angle shear surfaces; and,
- Sliding of fault-bounded blocks of bedrock along shear planes due to loss of lateral support.

The first type of ground movement is referred to as a landslide. The second and third types are called earth block slips or landslips (Golder, 1995a). The first two types of ground movement are the result of long-term natural geologic processes. The third type of movement may be caused by human activities, such as pit excavation. All three types can be exacerbated by human activities.

Known features that have moved recently are described in Section III.A.2.b of the 1997 Draft EIS. No ground movements have been documented outside of the pit since the 1998 Final EIS was prepared.

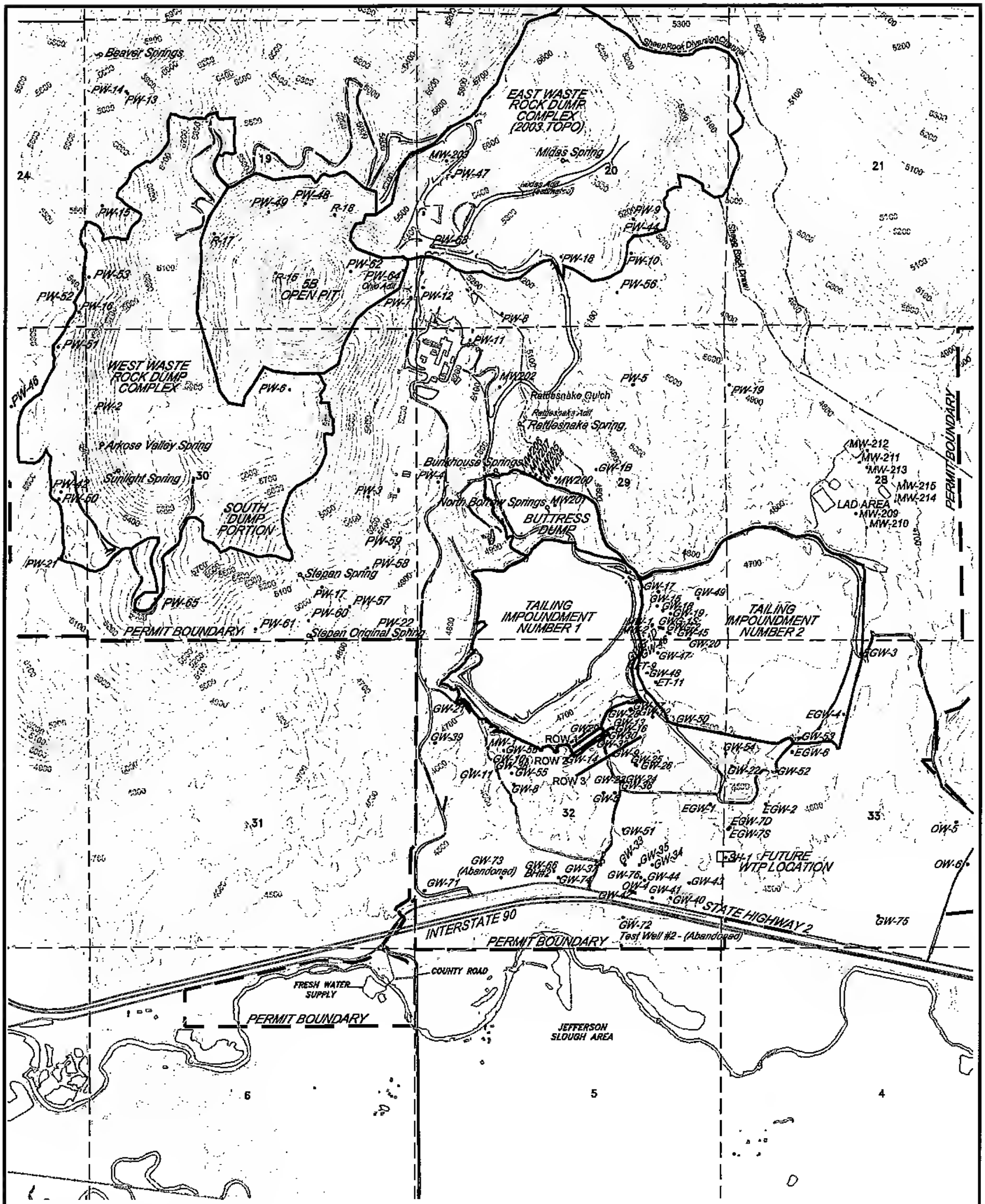
3.2.2.2 Faulting and Seismicity

GSM is located in a region known as the Intermountain Seismic Belt (ISB) (Smith and Sbar, 1974; Stickney and Bartholomew, 1987). The ISB is sharply defined in this area

by historic seismicity along about a 50-mile-wide, northerly trending zone. Ninety-five percent of the earthquake activity in the region occurs within this zone. Most of the historically measured earthquakes in the vicinity of the site are very small and are referred to as micro-earthquakes.

Details on geology in the area of the open pit and East Waste Rock Dump Complex are provided in Sections 3.2.1.2 and 3.2.1.4 of this SEIS and in Section III.A.2.d of the 1997 Draft EIS. Additional details are discussed in Telesto (2003d). This report analyzed the stability of the GSM pit highwall under two reclamation alternatives and examined the factors affecting the long-term aspects of these alternatives. Stability for circular failure was analyzed using SLOPE/W (GEO-SLOPE International, 2001) with the soil and rock mass strength parameters obtained from the laboratory (Golder, 1992a and1992b). The review of the slope stability results for the East Waste Rock Dump Complex shows that the factors of safety ranging from 1.3 to 1.5 are conservative (Golder, 1995a and 1995b). The factor of safety is a calculation defining the relationship of the strength of the resisting force of an element (C) to the demand (D) or stress of the disturbing force where F=C/D. When F is less than 1, failure can occur.

GSM conducted additional studies at the site after a 3.5 magnitude earthquake occurred close to GSM on June 28, 2004 (AMEC, 2004). It was felt at the mine, but no damage was done and no highwall instability occurred. GSM evaluated previous values used in seismic analyses and confirmed these were reasonable and appropriate (Brawner, 2005; Golder, 2005a and 2005b).



Rattlesnake Gulch Interception Wells
MW-204, MW-205, MW-206, MW-207

South Pumpback Wells
9 Wells, Row 1
10 Wells, Row 2
20 Wells, Row 3

0 1200 2400
Scale In Feet

SPRING AND MONITORING WELL LOCATIONS IN FACILITIES AREA

FIGURE 3-5

Figure 3-5 springs.dwg Rev. 1/2006

3.2.2.3 Mine Pit Highwall

The main portion of the mine pit is roughly circular in plan view (Figure 2-1). The lowest part of the pit rim on the east side is at approximately the 5,350-foot elevation (Figure 2-3). The main floor of the pit is permitted to an elevation of 4,650 feet. The pit has a crest elevation of approximately 6,400 feet at the northwest side, and the pit is permitted for 336 acres of disturbance (GSM, 2002). The immediate pit area disturbance is 218 acres, based on an April 2004 disturbance accounting using the 2002 aerial photograghs as the base. This disturbance would not expand under the approved Stage 5B mining operations. The SEIS analyzes GSM's proposal to deepen the pit floor to 4,525 feet.

The pit has been redesigned since the 1998 Final EIS as described in Section 2.2.4. The pit highwall is characterized by slopes and benches (Figure 2-3). A 50-foot height between benches was typically used, with some benches being up to 100 feet in height. The width of the benches varies, depending on the desired overall pit highwall slope angle. A minimum bench width of 22 feet is used for 50-foot-high benches. Previously, the angle of the faces between the benches was 45 degrees in sediments and 49 degrees in breccia. Steeper pit highwalls have been made possible (53 degrees in sediments and 60 degrees in breccia) by using presplit and controlled blasting techniques within 50 feet of the pit highwall and scaling of pit highwall with an excavator (see Section 4.2.1.2.1). Controlled blasting results in a pit highwall where structural features, such as faults, bedding planes, joints, fractures, and the highwall rock, are less disturbed compared to the previous mining methods used. There is considerably less broken and fractured rock left on the highwall as a result of controlled blasting and scaling. Whenever the pit highwall is steepened, there is the possibility of intersecting geologic structures that would have been stable at a flatter highwall angle. Controlled blasting has a less detrimental effect on the strength of structural features by reducing disturbance of these structures.

Along the general trend of the northwest pit highwall, there is a series of faults that dip to the southeast and northwest at 70 to 90 degrees. These faults and their intersections with low-angle bedding planes and joints have the potential to generate wedge failures within the pit. The last two wedge failures were on the northwest part of the pit highwall. Slopes along the northwest wall of the pit were flattened as part of the modified pit design in order to mitigate stability problems during the life of the mine due to the unfavorable orientation of these features.

Several factors at GSM indicate that physical or chemical weathering is not likely a factor in highwall stability. The host breccia rock consists predominantly of well-cemented sandstones and shales. Both field observations and petrographic examination indicate that the host rocks are hard with little or no porosity or internal fracturing (Telesto, 2003d). The hydrology of the host rock has been characterized as fracture dominated, which means the diffusion of oxygen or flow of oxygenated water occurs largely in the fractures and not in the host rock matrix. The 0.5 to 2.0 percent

sulfide content of the waste rock has the effect of consuming any available oxygen at the surface of the rock, further limiting the ability for the rocks to chemically weather deeply (Telesto, 2003d).

3.3 WATER RESOURCES AND GEOCHEMISTRY

The 1997 Draft EIS, particularly Chapter IV, was reviewed and a number of data needs were identified with respect to evaluating potential impacts to groundwater leaving the pit area. The following tasks were completed to provide the technical information required for the SEIS:

- A re-analysis of the pit hydrology and pit water balance was conducted based on field data that were not available at that time (Telesto, 2003a & b; Telesto, 2006; HSI, 2006).
- The 1997 Draft EIS, Section III.B.2 relied on groundwater elevation data from 1993 and treated the Precambrian bedrock and Tertiary/Quaternary (T/Q) alluvial aquifers as a single hydrologic unit. For this SEIS, a potentiometric map was prepared using only 2003 data from T/Q wells and springs to better define potential groundwater flow paths within the T/Q sediments away from the pit and the East Waste Rock Dump Complex (HSI, 2003).
- The hydrogeologic and ARD attenuation characteristics of the groundwater flow path from the pit were used to provide a basis for evaluating and comparing alternatives (HSI, 2003).
- The characteristics of the flow path from the East Waste Rock Dump Complex were re-evaluated to ensure that a consistent basis was used for comparing the East Waste Rock Dump Complex and the pit (HSI, 2003 and 2006).
- The pit backfill geochemistry was evaluated in detail (Telesto, 2003c).
- The East Waste Rock Dump Complex mineralogy was characterized (Telesto, 2003h, 2003j, 2005a).

3.3.1 Hydrostratigraphy

The groundwater hydrology of the area was documented in detail in the 1997 Draft EIS, Chapter III, Section B.2, which identified the following hydrogeologic units or aquifers:

- Precambrian fractured bedrock (bedrock aquifer)
- Tertiary Bozeman Group sediments (Bozeman Group aquifer)
- Tertiary to early Quaternary alluvium (T/Q alluvial aquifer)
- Tertiary debris flow/colluvial materials (Tdf/colluvial aquifer)
- Jefferson River alluvium (Jefferson River alluvial aquifer)

3.3.1.1 Bedrock Aquifer

The fractured Precambrian bedrock is the primary hydrogeologic unit that occurs in the pit area and west of the Bull Mountain area (Figure 3-1). As described in Section 3.2.1, the bedrock consists of several different rock types.

Bull Mountain groundwater flow in the bedrock aquifer is controlled by secondary geologic features. The ability of an aquifer to transmit water is defined by its permeability, which is measured in units of length per unit time. The permeability of the bedrock aquifer is a function of the heterogeneous fracture porosity. Depending on the fracture width, spacing, abundance, and orientation, some fracture systems will transmit more water than others. Bedrock permeability varies on a local scale, but when examined on a regional scale, bedrock permeability can be characterized by an average or bulk permeability. Regional analyses yield bulk bedrock permeabilities with values on the order of 1×10^{-6} centimeters/second (cm/sec) to 1×10^{-7}cm/sec, with generally lower values in deeper bedrock (1997 Draft EIS, Chapter III, Section B).

3.3.1.2 Bozeman Group Aquifer

The Bozeman Group aquifer is a hydrogeologic unit that occurs east and south of Bull Mountain where it overlies the bedrock unit. It is comprised of alternating and interfingering layers and lenses of sand, silt, and clay deposited in a fluvial (river or stream) environment. Inspection of drill cuttings has shown fine to coarse-grained sand intermixed within clay and thin sand and gravel lenses. The discrete layers of clay, silt, sand, and fine gravel within the Bozeman Group sediments are discontinuous due to the fluvial depositional environment. The frequency of occurrence of sand and gravel lenses suggests that these lenses are interconnected to some degree, controlling the primary permeability of the unit. The Bozeman Group sediments typically have a low bulk permeability on the order of 2.5×10^{-5} to 7×10^{-6} cm/sec due to the abundance of silt and clay, but they can locally exhibit relatively high permeability in sand and gravel layers and lenses (1997 Draft EIS, Chapter III, Section B.2.a).

3.3.1.3 Tertiary/Quaternary Alluvial Aquifer

The Tertiary/Quaternary colluvium and alluvium were deposited on the Bozeman Group sediments. This unit consists of locally derived gravels in a silty sand matrix that also may include reworked Bozeman Group sediments and older Tertiary fan terrace deposits consisting of sand, gravel, and clay. Younger alluvial sand and gravel found in modern drainages in the area also are included with this unit, since they share similar textural characteristics with the older deposits. This unit is thickest adjacent to the East Waste Rock Dump Complex area on the east side of Bull Mountain and thins to the south and east. Aquifer tests of the Quaternary alluvium and colluvium indicate permeability in the range of 1×10^{-3} to 1×10^{-4} cm/sec, with localized values as high as 2×10^{-2} cm/sec (Hydrometrics, 1995; SHB, 1981).

3.3.1.4 Tertiary Debris Flow/Colluvial Aquifer

This unit is present locally on the east side of Bull Mountain and is most important in Rattlesnake Gulch in terms of areal extent and saturated thickness. Geologic cross sections indicate that the unit comprises a relatively continuous series of channelized sediments that exist from just east of the open pit to the north end of Tailings Impoundment No. 1 (Golder, 1995a; HSI, 2003). Depending on location, the unit may be exposed at the surface or overlain by recent alluvium and colluvium. The hydraulic conductivity of the unit is estimated to range from $1x10^{-3}$ to $1x10^{-4}$ cm/sec (Golder, 1995a). Saturated thickness within the unit ranges from in excess of 100 feet beneath the mill site to tens of feet where the unit thins and is exposed at the surface. Saturated thickness within the unit has been reduced by the Rattlesnake Gulch groundwater interception wells, which produce approximately 50 gpm (HSI, 2003; Telesto, 2006). This unit appears to convey the majority of groundwater flow in the Rattlesnake Block down Rattlesnake Gulch (Golder, 1995a). Based on data collected by GSM since 1998, the pumping rate from the Rattlesnake Gulch interceptions wells has been approximately 50 gpm, and the pumping rate from the South Pumpback wells in Rattlesnake Gulch has been approximately 30 to 50 gpm, for a combined total of about 100 gpm (S. Dunlap, personal communication, 2006). The East Flank Pumpback wells are outside Rattlesnake Gulch and have been producing a combined total of approximately 50 gpm. Seasonal and annual fluctuations occur.

3.3.1.5 Jefferson River Alluvial Aquifer

The Jefferson River alluvial aquifer is near the southern permit area boundary and consists of unconsolidated gravel, sand, and finer-grained channel and overbank deposits (Figure 3-1). Saturated thickness of the aquifer within the permit boundary is estimated to be approximately 20 feet in lower, recent alluvium (SHB, 1986) and 5 to 15 feet in the upper terraces (Spectrum Engineering and Gallagher, 2004). The majority of inflow to the Jefferson River alluvial aquifer south of GSM is through-flow from the west. Smaller amounts are contributed from the T/Q alluvial aquifer and Tdf/colluvial aquifer at the mine site to the north (SHB, 1986). Most of this groundwater is captured by the Rattlesnake Gulch and South Pumpback capture systems operated by GSM. The Jefferson River alluvial aquifer is in direct contact with the Tdf and alluvial channel aquifer that underlies Tailings Impoundment No. 1 to the north (SHB, 1985; HSI, 2003). The primary direction of groundwater flow in the Jefferson River alluvial aquifer is to the east (SHB, 1985; Spectrum Engineering and Gallagher, 2004). Hydraulic conductivity estimates for the Jefferson River alluvial aquifer are approximately $2x10^{-1}$ cm/sec (SHB, 1986). Pumping rates ranging from 10 to 300 gpm have been reported on drillers' logs filed with the Montana Department of Natural Resources and Conservation (DNRC) (SHB, 1987). A groundwater gradient of 0.0015 has been documented within the Jefferson River alluvial aquifer, with groundwater seepage velocities estimated to be 3.8 to 4.8 feet per day, indicative of a highly permeable groundwater flow system (SHB, 1986; HSI, 2003; Spectrum Engineering and Gallagher, 2004).

3.3.2 Potentiometric Surface in the Tertiary/Quaternary Aquifer

A potentiometric map displays contours of equal elevation of the total hydraulic head and pressure in a particular aquifer with water table or groundwater elevations identified. These maps are routinely used to obtain directions of groundwater flow. In the 1997 Draft EIS, Chapter III, Section B.2.a, groundwater elevation data were used to develop a generalized regional potentiometric map of the mine area for late season 1993 conditions (Chapter III, Figure III-5).

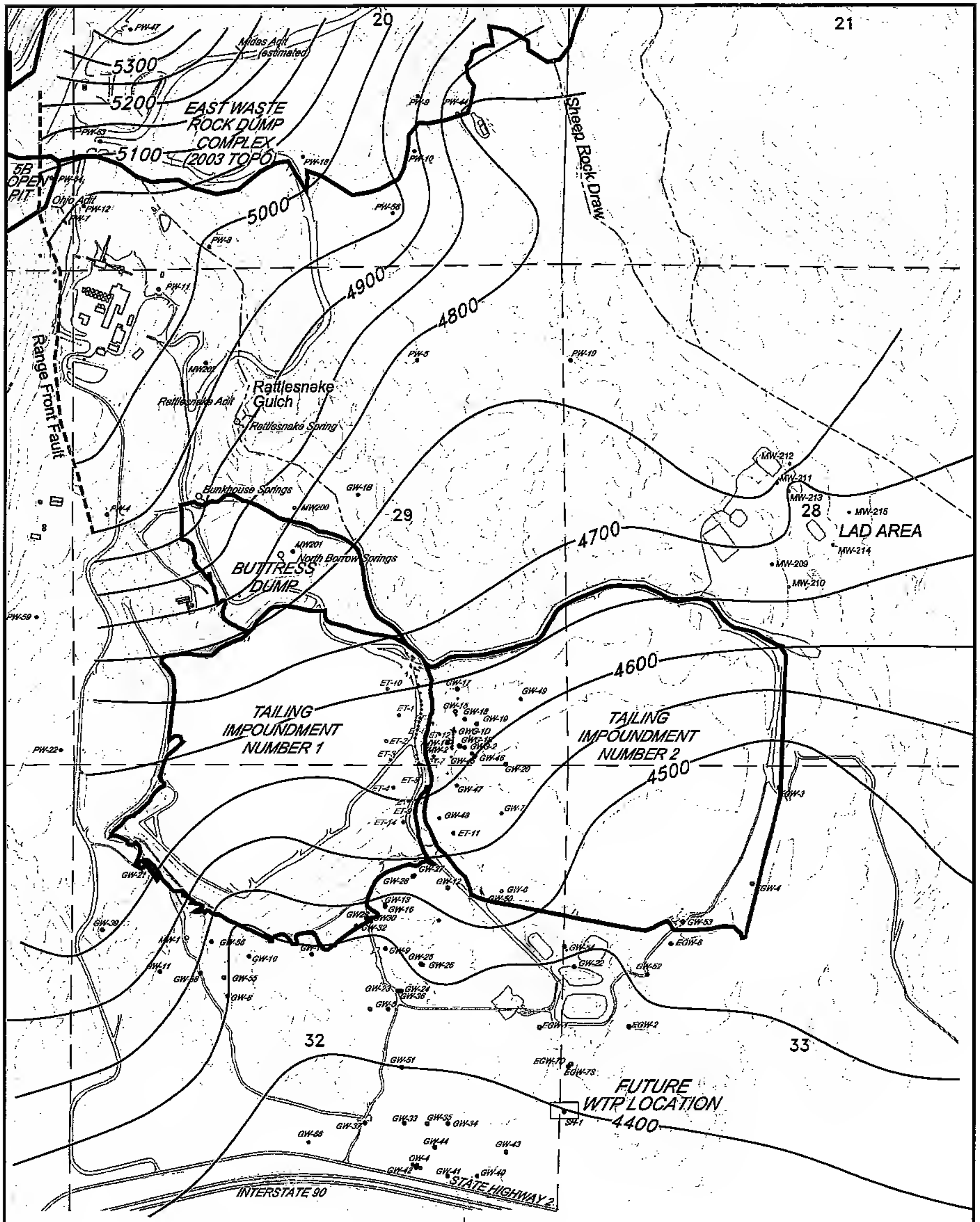
The new potentiometric map (Figure 3-6), which focuses on the Tertiary and Quaternary aquifer system, was constructed for the following reasons:

- To characterize groundwater flow paths in the Tertiary and Quaternary sediments downgradient from the open pit and the East Waste Rock Dump Complex;
- To update the potentiometric map to current site conditions;
- Analyses in this document treat the bedrock aquifer and the Tertiary and Quaternary aquifer as separate hydrologic units.

The new potentiometric map represents groundwater elevations from selected wells that are completed only in the Tertiary and Quaternary aquifer (Figure 3-6). Wells were selected for inclusion in the map based on the geologic map of GSM (GSM, 1996) and a review of well completion details (GSM Annual Reports). Some wells were eliminated from the potentiometric map because they were screened in a perched aquifer, for example, within the tailings impoundments, or very deep in the Bozeman Group sediments, which gives a relatively low head, or they are near the land application disposal (LAD) infiltration pond (HSI, 2003).

In the area between Tailings Impoundment No. 1 and the Jefferson River alluvial aquifer, a saturated sand and gravel channel is incised into the Bozeman Group aquifer (Hydrometrics, 1994; Keats, 2001). Where this sand and gravel aquifer was hydrologically continuous with the upgradient Tdf/colluvial aquifer (Golder, 1995a), data from wells in the Quaternary deposits were utilized so that the uppermost and potentially the most rapid groundwater flow path was addressed.

The Jefferson River alluvial aquifer grades into the T/Q alluvial aquifer on the GSM property several hundred feet north of I-90. Studies by Hydrometrics (1994), Keats (2001-2002), and Spectrum Engineering and Gallagher (2004) indicate that these aquifers are hydrologically connected. Therefore, the potentiometric map included data from wells completed in the Jefferson River alluvial aquifer, including the southernmost GSM monitoring wells along the permit boundary and private water wells in the valley just south of the boundary. Elevations of the private wells were estimated from the United States Geological Survey (USGS) topographic map and adjusted (+91.4 feet) to GSM datum.



LEGEND

Potentiometric Contour Line (50 Foot Interval)

0 750 1500
Scale In Feet

GENERALIZED POTENTIOMETRIC MAP OF THE TERTIARY/QUATERNARY SEDIMENTS EAST OF THE PIT (May - June 2003)

FIGURE 3-6

Figure 3-6 potent.dwg

3.3.3 Groundwater Quality

The 1997 Draft EIS, Chapter III, Section B.2.b described groundwater quality in the GSM project area as highly variable and identified eight regions with distinct water quality characteristics, some of which are related to mine facilities. For the purpose of the SEIS, updated water quality data obtained from GSM's Annual Reports (GSM, 1998-2004; Portage, 2004) for groundwater monitoring wells, springs, and the pit sump (see Figure 3-5 for well and spring locations) were reviewed for trends in acidity (measured in pH standard units) and sulfate concentrations that might indicate changes relevant to the alternatives analyzed. The majority of monitoring wells and springs exhibit stable ranges of pH and sulfate.

The following trends were observed in the data:

- A small number of wells in the bedrock aquifer and the Tdf/colluvial aquifer (PW-8, PW-11, PW-14, and PW-15) show decreases in sulfate concentrations that appear to correlate to decreasing water-level trends (Figure 3-5).
- PW-6, which is located south of the pit in the bedrock aquifer, reflects a decrease in pH from a range of 5-6 to 3 (Figure 3-5). The well also experienced a decreasing water-level trend during this period.
- PW-17, which is located down gradient from Stepan Spring in the bedrock aquifer, had a strong increase in sulfate concentration between 1997 and 2000. Reclamation work in the Stepan Spring area in late 1999 (see discussion in Section 3.3.4) has reversed the sulfate trend in PW-17 (Figure 3-5).
- The pit sump water quality has been monitored from 1999 to present. Water quality decreased substantially in early 2002, coincident with allowing pit water to collect in rubble at the bottom of the pit. The pH range of the pit water decreased from 5-7 to 4-5, and the sulfate concentration increased from approximately 5,000 milligrams/liter (mg/l) to 20,000 mg/l.

3.3.4 Seeps and Springs

Concerns were raised during the MAA process that seeps and springs at GSM may have been affected by mining operations. A detailed analysis of springs in the GSM project area was presented in Chapter III, Section III.B.2.d of the 1997 Draft EIS. A summary of the spring survey with updated water quality information as of December 2002 is presented in Table 3-1 with spring and well locations shown on Figure 3-5.

Most springs and seeps within the area generally discharge only a few gallons per minute, and some can cease flowing during dry seasons when the water table is low or during freezing conditions during winter. The major springs and seeps that have been mapped within and adjacent to the pit area and are currently accessible include Rattlesnake Spring, Bunkhouse Springs, Stepan Spring, and Stepan Original Spring.

Surface seeps existed in the Midas Spring, North Borrow Springs, Sunlight Spring, and Arkose Valley Spring areas (Figure 3-5), but have since been intercepted by drain systems to allow placement of waste rock. The drains were constructed to prevent contact between water and waste rock materials.

Some springs downgradient of the pit area have ARD signatures (low pH, elevated concentrations of sulfate, and trace metals). These include Rattlesnake Spring, Bunkhouse Springs, Stepan Spring, Stepan Original Spring, and North Borrow Springs (Table 3-1). All of these, with the exceptions of Bunkhouse Springs and North Borrow Springs, can be associated with mineralized geologic structures or with abandoned mine adits which interconnect to mineralized zones (Gallagher, 2003a). The abundance of 11,000-year-old ferricrete associated with Rattlesnake Spring, Bunkhouse Springs, Stepan Spring, and Stepan Original Spring indicates that ARD discharge is likely to have occurred for thousands of years before mining began. Bunkhouse Springs occurs within Tertiary debris flow deposits and may originate due to the presence of discrete high permeability conduits within the colluvium.

A reclamation project was conducted at the site of Stepan Spring in late 1999 due to a trend of decreasing water quality thought to be related to dump face runoff from the South Dump (Gallagher, 2003d) (Figure 1-2). The reclamation project included:

- Completion of the reclamation of the South Dump and channeling of the historic flow from the toe area;
- Removal of pre-GSM historic mining waste rock and debris;
- Excavation of a channel;
- Placement of a substrate of pebble-sized limestone;
- Placement of a growth medium;
- Creation of benches between the channel and the sides of the gulch;
- Covering areas with limestone armoring; and,
- Placement of straw and seeding the entire area with dryland and wetland species.

The reclamation project resulted in an overall improvement in water quality and a decrease in flow rate from 1999 to 2002 (personal communication (GSM data), Gallagher, June 30, 2003). From 2002 to 2006, the flow rate decreased to intermittent, TDS and Sulfate have increased slightly, and pH has decreased from a range of 5 to 6 to a range of 4 to 5 (Shannon Dunlap, GSM personal communication 2006).

Table 3 - 1. Summary of Springs Downgradient of the Pit

Spring/ Seep Name	Location[1] (shown on Figure 3-5)	Elevation[2] (feet)	Origination[1]	Flow Rate[3] (gpm)	WQ[4]		Other
					pH	Sulfate (ppm)	
Rattlesnake	Southeast of plant site along Rattlesnake Fault	4,940	believed to originate in adit; represents regional system discharge (constant rate)	baseflow 0.2 to 0.6	(3.8-5.3) slightly acidic	309 to 359	represents Bozeman Group aquifer water and upgradient bedrock aquifer (mineralized) water
Bunkhouse	Southwest of Rattlesnake Spring (RS), south end of RS Block	4,930	surface expression of the regional water table in the area	0.6 to 7 (baseflow 1-2)	(4.3-6.8) slightly acidic	598 to 733	receives flow from mineralized zones; reacts to precipitation events
Stepan	Southeast of the South Dump	5,025	represents discharge from mineralized zones in bedrock aquifer	0.2 to 1.4	(2.8-4.7) acidic	1,760 to 9,170	does not receive substantial recharge from drainage area
Stepan Original	1,600 feet southwest of Stepan Spring	4,888	collapsed abandoned adit; represents regional groundwater which has traveled through mineralized zones in bedrock aquifer	0.8 to 2.8	(5.2-6.2) slightly acidic to neutral	1,790 to 2,200	measurement range attributed to inconsistent measurement methods; little variation in flow
Sunlight	Near top of southwest section of West Waste Rock Dump Complex	5,312	possibly related to Latite Valley fault	0 to 6			covered by gravel trench system
Arkose Valley	Near top of southwest section of West Waste Rock Dump Complex, north of Sunlight	5,298	possibly related to Latite Valley fault	Approx < 1			covered by gravel trench system
Buried springs/seeps (engineered systems)							
North Borrow	120 yards north of Tailings Impoundment No. 1 in Rattlesnake Gulch drainage	4,790	created when North Borrow area excavated below shallow water table	8 to 32	(3.9-6.3) slightly acidic	not reported	intercepted by an underdrain; area filled by Buttress Dump expansion

[1] summarized from 1997 Draft EIS text, Chapter III, Section B.2.d

[2] estimated from "Generalized Potentiometric Map of Late Season 1993 Groundwater Conditions in GSM Project Area"; elevations relative to GSM datum; minus 91.4 feet to convert to USGS datum

[3] summarized from GSM Pit Area Spring and Seep Data 1990 to 2002 (Gallagher, 2003b; GSM 2004 Annual Report)

[4] read off graphs in 1997 Draft EIS text, Chapter III, Section B.2.d

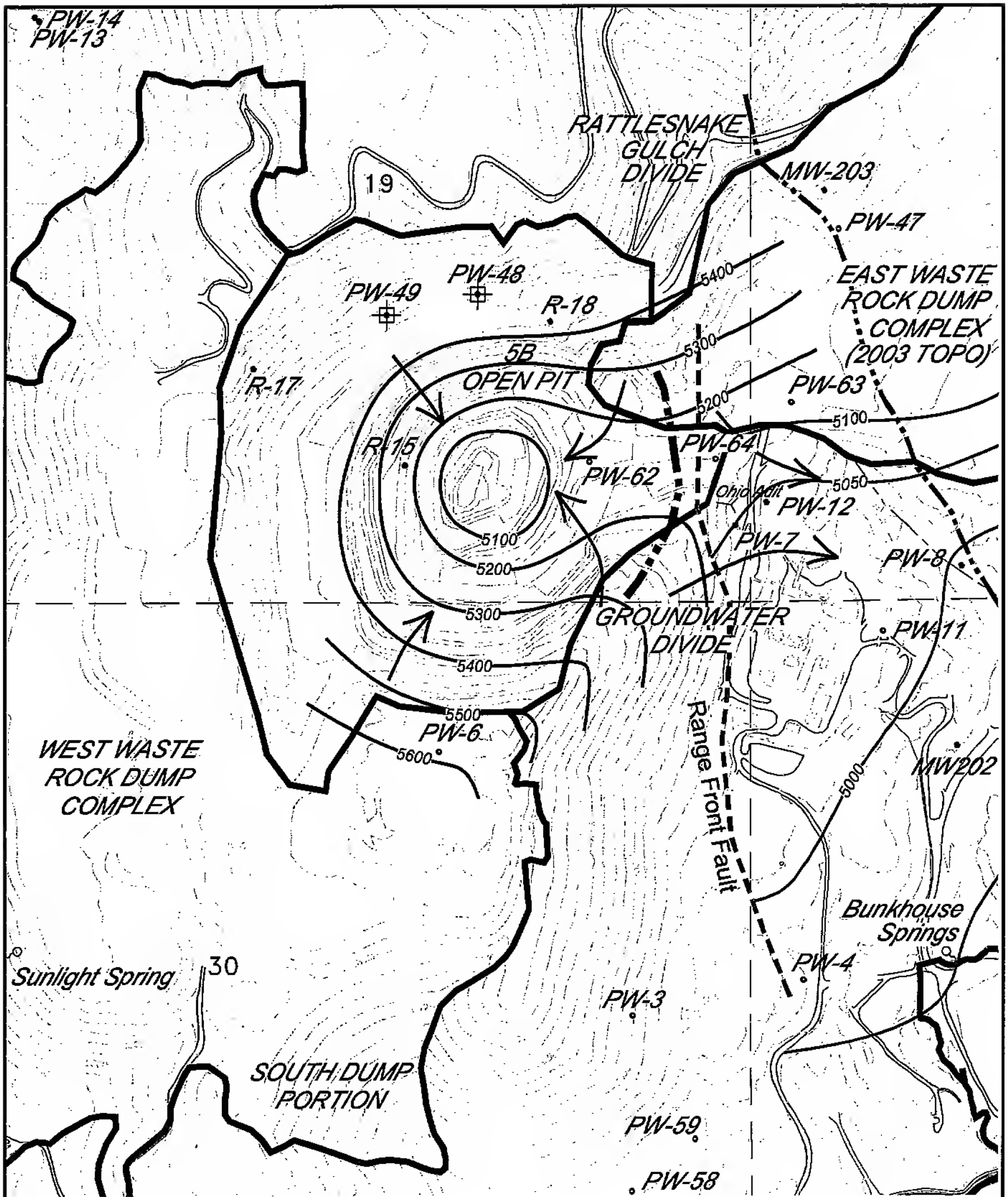
3.3.5 Groundwater in the East Waste Rock Dump Complex

No groundwater is predicted to enter the East Waste Rock Dump Complex from upgradient. The 1997 Draft EIS, Appendix J, Table J-4 predicted that 6 to 10 gpm of water from precipitation and runon would leave the East Waste Rock Dump Complex. Sheep Rock Creek was diverted around the East Waste Rock Dump Complex as part of Amendment 010 approval (1998 ROD).

No flow has been observed from the East Waste Rock Dump Complex and none was predicted for 54 to 433 years (1997 Draft EIS, Appendix J). This value has been adjusted to 33 to 72 years based on technical work for this SEIS as presented in Section 4.3.2.1.1.1.4. No dewatering wells were required as the predicted flow from the East Waste Rock Dump Complex was to be attenuated in the Bozeman Group sediments and mixed with ambient groundwater and would meet groundwater quality standards at the mixing zone boundary (1997 Draft EIS, Appendix B).

3.3.6 Groundwater in the Pit Area

The pit is currently maintained as a hydrologic sink as described in Section 3.3.7.2. A generalized depiction of groundwater elevations in the vicinity of the pit in September 2001 is shown on Figure 3-7. In the 1997 Draft EIS, Chapter II the agencies predicted that 102 gpm (Section II.B.2.b, page 69) of groundwater would need to be pumped and treated under the No Pit Pond Alternative and 47 gpm (Section II.B.7.b, page 100) under the Partial Pit Backfill Alternative. The 1997 Draft EIS, Chapter IV, Section IV.B relied on model simulations of the local pit groundwater system as the primary basis for evaluating impacts to water quantity from pit dewatering (Hydrometrics, 1995). A detailed discussion of the groundwater model configuration and input parameters can be found in Volume 3, Appendix 4.7-1 of GSM's Permit Application (GSM, 1995b). This SEIS uses additional studies, including a pit hydrogeology investigation (URS, 2001), a pit highwall seep study (Gallagher, 2003b; Telesto, 2006), a water balance model of the pit (Telesto, 2003b and 2006), an analysis of well and spring hydrographs (HSI, 2003), and an analysis of groundwater flowpaths from the pit (HSI 2003; HSI 2006; Spectrum Engineering and Gallagher, 2004).



LEGEND

- Groundwater Divide
- 5100 — Potentiometric Line with Elevation (As of 9/2001)
- Groundwater Flow Direction
- PW-6 ● Groundwater Monitoring Well
- Approximate Location of Range Front Fault
- PW-49 Existing Dewatering Wells

Source: GSM Operating Permit No. 00065
Partial Pit Backfill Plan - October, 2002

0 500 1000
Scale in Feet

GENERALIZED POTENTIOMETRIC SURFACE OF GSM OPEN PIT AREA

FIGURE 3-7

Figure 3-7 gwflow.dwg Rev. 1/2006

A groundwater divide is located between wells PW-64 and PW-62 (URS, 2001) and is shown near the eastern edge of the pit in Figure 3-7. Recent groundwater elevations in PW-62 and PW-64 have ranged between 5,145 and 5,192 feet, and the groundwater divide is expected to be between those elevations. Groundwater west of the divide flows into the pit; groundwater east of the divide flows eastward into the Tdf/colluvial aquifer.

Faults and fractures control the permeability of the bedrock aquifer in the pit area and act as the conduits of groundwater flow into the pit. During mining, the pit has been continually dewatered from within the pit and from two vertical dewatering wells on the north side of the pit (PW-48 and PW-49 as shown on Figure 3-5). From 1995 through 2001, 43 pit highwall seeps were cataloged by GSM, some of which are probably duplicative, due to the changing pit configuration and seep locations over time (Gallagher, 2003b). The most seepage was found as the pit penetrated the Corridor Fault. In general, while new seeps have been identified as the pit was enlarged and deepened, total flow from seeps has not changed proportionately. At present, most groundwater flows into the pit along the north wall of the pit where the Corridor Fault is intersected. On the south pit highwall, the Sunlight and Fenner faults appear to be secondary sources of groundwater inflow (Figure 3-2).

The 1997 Draft EIS and other previous reports used the term "regional groundwater flow" to describe the majority of groundwater that flows into the pit. Fetter (1980) describes a regional flow system as having its recharge area at the basin divide and discharge area at the valley bottom. Local and intermediate flow systems have shorter flow paths that are influenced by variations in local topography, and may react quickly to precipitation events. Additional analyses indicate that most of the groundwater inflow to the pit is best characterized as intermediate and local groundwater flow (Gallagher, 2003a). Recharge to the pit is generally topographically controlled and is conveyed primarily by structures having higher permeability. Precipitation events were found to be responsible for the largest variations in pit highwall seep flows (Gallagher, 2003b). Precipitation events result in an almost immediate increase in flow (local flow system) from major seeps along the Corridor Fault. A general decay of the flow rate can be observed over time following a precipitation event, indicating influence from the intermediate flow system.

Gallagher's (2003b) spring and seep report also described the geologic structural controls, lithologic controls, and engineering/blasting controls on pit highwall seepage. A disturbed rock zone caused by conventional blasting and mining extends several feet to tens of feet into the pit highwall. This zone tends to funnel pit highwall inflows downward, where the seepage may reach the pit bottom, or may emerge as pit highwall seeps. As described in Section 3.2.2.3, GSM has refined its blasting method in the lower portion of the pit, which has reduced the thickness of the disturbed rock zone.

Based on GSM's experience in dewatering the pit for the past 7 years and a new pit water balance model (Telesto, 2003b and 2006), the total net inflow to the pit (total inflow minus evaporation) is projected to be between 25 and 27 gpm for the No Pit Pond

Alternative. The 1997 Draft EIS, Chapter IV, Section IV.B.2.b projected a maximum total net inflow of 102 gpm for the No Pit Pond Alternative. The difference between the two estimates is due to an earlier underestimation of evaporation, less than predicted pit inflows, and the potential influence of drought. The hydrogeologic and water balance studies performed for the SEIS predict that for a 10-year time-weighted average, the majority (136 gpm) of the inflow to the pit would be direct precipitation and runon, with 22 to 37 gpm entering as groundwater inflow through seepage along faults and fractures, primarily from the Corridor Fault (Telesto, 2006). Faults penetrating the lower portions of the pit yield much less water than the Corridor Fault. The underground mine, which reaches approximately 300 feet (4,400-foot elevation) beneath the current pit bottom, had very small amounts of inflow after fractures drained, and water was imported to maintain underground mining operations.

The new water balance study predicts that for the Stage 5B pit, the majority (132 to 145 gpm) of the water that enters the pit will exit as evaporation (Telesto, 2006). The highwall has a high evaporation potential due to its aspect, color, and large surface area. Most water enters the pit at or above the bottom of the Corridor Fault, and must flow over a large portion of exposed rock in order to reach the bottom of the pit, thus resulting in a large evaporation loss. Some water may also be lost during exothermic reactions with exposed sulfides.

3.3.7 Groundwater Flow Paths

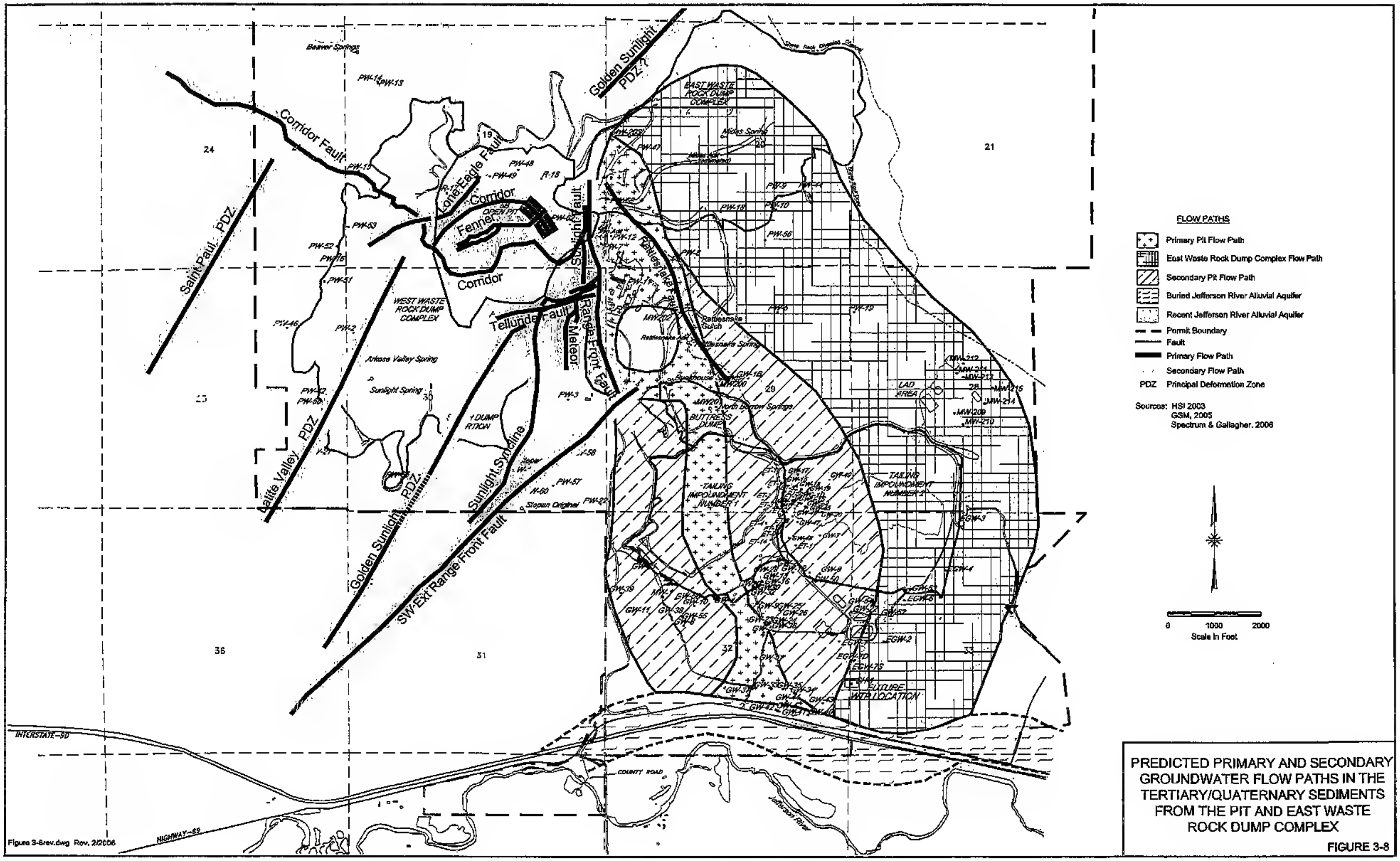
3.3.7.1 Groundwater Flow Path from the East Waste Rock Dump Complex

Groundwater flow beneath the East Waste Rock Dump Complex is to the south, principally in the Tertiary gravels and Tertiary alluvial deposits initially, transitioning into the Tertiary fluvial deposits farther south. Although the bulk permeability of the Bozeman Group aquifer is not high, beds of fine to coarse sandstone and pebbly conglomerate do provide preferential pathways for groundwater movement. Groundwater beneath the 13 percent portion of the East Waste Rock Dump Complex in the Rattlesnake Gulch drainage would likely report to the Tertiary to Quaternary debris flow and alluvial channel deposits in Rattlesnake Gulch.

Below the veneer of Quaternary deposits, typically 80 feet (ranges from 60 to 150 feet) of unsaturated Tertiary sediments underlie the East Waste Rock Dump Complex (HSI, 2003). Saturation is present in the lower portion of the Tertiary gravels and Tertiary alluvial deposits. The earth slip blocks that moved at GSM in 1994 moved on or near the contact of the Tertiary alluvial and Tertiary fluvial deposits (Golder, 1995a). About seventy percent of the East Waste Rock Dump Complex overlies Tertiary deposits. The groundwater flowpath downgradient of the East Waste Rock Dump Complex is principally in Tertiary alluvial and Tertiary fluvial deposits. The potentiometric map of the T/Q alluvial aquifer (Figure 3-6) indicates that this groundwater flow system is hydrologically connected to the Jefferson River alluvial aquifer, approximately 12,500 feet to the south.

The 1997 Draft EIS, Appendix J, Table J-4 predicted that 6 to 10 gpm of water would leave the dump and follow the groundwater flow path from the East Waste Rock Dump Complex to the Jefferson River alluvial aquifer (Figure 3-8). This flow path is interpreted to be hydraulically controlled, that is, dictated by the potentiometric gradient.

About 13 percent of the East Waste Rock Dump Complex at the southwestern tip overlies debris flow deposits that are part of the same sand and gravel flowpath described below for the pit. Groundwater beneath this area migrates south, mixes with other groundwater in the Tdf/colluvial aquifer, and continues to move down gradient in that flow path along Rattlesnake Gulch. The 1997 Draft EIS, Chapter IV, Section IV.B.1.e predicted that 200 gpm of natural groundwater would flow down Rattlesnake Gulch and would have to be collected and treated with Tailings Impoundment No. 1 seepage. GSM drilled the Rattlesnake Gulch dewatering wells above Tailings Impoundment No. 1 in 1994 in association with the Buttress Dump (Figure 3-5). Most of this water is now captured by the wells and does not mix with tailings impoundment seepage. The rest of the groundwater flow is subject to capture by the south pumpback system that collects seepage from Tailings Impoundment No. 1 (Figure 3-5). Evaluations indicate the capture systems are completely or nearly completely capturing all groundwater in the Quaternary alluvial aquifer and the majority of water in the Bozeman Group aquifer. The minor quantity of uncaptured groundwater may reach the Jefferson River alluvial aquifer via coarser units within the Bozeman Group aquifer (Hydrometrics, 1994 and 1997; Keats, 2001 and 2002; Spectrum Engineering and Gallagher, 2004).



PREDICTED PRIMARY AND SECONDARY GROUNDWATER FLOW PATHS IN THE TERTIARY/QUATERNARY SEDIMENTS FROM THE PIT AND EAST WASTE ROCK DUMP COMPLEX

FIGURE 3-8

3.3.7.2 Groundwater Flow Paths from the Pit Area

The open pit is currently maintained as a hydrologic sink by pumping from the bottom of the pit and two vertical highwall dewatering wells (PW-48 and PW-49, Figure 3-5). Under current conditions, almost all of the water entering the pit area is believed to be captured by the pit, and removed by evaporation or pit dewatering activities.

The primary historic flow path out of the pit area was the Corridor Fault, which was encountered at an elevation of approximately 5,250 feet near the northeast corner of the pit (URS, 2001; Gallagher, 2003b; Telesto, 2003b). In addition, other, less permeable structural flow paths exist lower in the pit. The hydrogeologic setting, along with the previous documentation of abundant ferricrete deposits in the T/Q materials immediately below the east and southeast side of the pit, as discussed in Section 3.3.6, provide evidence that the principal groundwater pathway from the pit area would have been via the Corridor Fault east and southeast to subsurface discharge beneath the access road area to the Rattlesnake Gulch drainage.

Some of this flow would be intersected by the Range Front Fault and migrate south to the intersection with the southwest extension of the Range Front Fault where some flow would likely travel along that fault and some flow would likely enter the sediments above Tailings Impoundment No. 1.

As mentioned in Section 3.3.7.1, the 1997 Draft EIS, Chapter IV, Section IV.B.1.e estimated that 200 gpm would flow beneath Tailings Impoundment No. 1, the majority of which would be groundwater flow from the Rattlesnake Gulch drainage area. The 1997 Draft EIS stated that 200 gpm was a conservatively high estimate and predicted that the flow would diminish based on operation of the various pumpback systems near Tailings Impoundment No. 1 and the Rattlesnake Gulch interception wells. Current pumping rates in Rattlesnake Gulch are discussed in Section 3.3.1.4.

A continuous high permeability pathway of Tertiary debris flow deposits from the pit to the north end of Tailings Impoundment No. 1 was mapped (Golder, 1995a). These debris flow deposits would be the potential primary flow path from the pit area if the pit were to become fully saturated (*i.e.* if a pit lake were to form, or if the pit were backfilled and water saturated). The Tertiary debris flow deposits appear to convey the majority of groundwater flow in the Rattlesnake Block (Figures 3-3 and 3-8). The relatively high permeability of these deposits is supported by the 52 gpm average yield of the Rattlesnake interception wells, and the far-reaching drawdown documented on the basis of hydrograph analysis (HSI, 2003).

The Tertiary debris flow gravel channel continues beneath Tailings Impoundment No. 1 and is hydrologically connected to the Jefferson River alluvial aquifer via younger alluvial channel deposits (HSI, 2003; Spectrum Engineering and Gallagher, 2004). This conclusion is supported by examination of numerous well logs and the contaminant migration patterns below the impoundment. Previous hydrogeologic studies by

Hydrometrics (1994 and 1997) used in the 1997 Draft EIS and by Keats (2001 and 2002) have identified this sand and gravel channel. Plotting of drilling logs from all studies demonstrates the continuity of this gravel channel from the pit to the river.

Secondary potential groundwater flow paths in the Tertiary/Quaternary deposits from the pit have been designated on Figure 3-8, based on the potentiometric head patterns. While the Tertiary debris flow channel in Rattlesnake Gulch is clearly the preferential pathway, potentiometric contours indicate that groundwater flow into the Bozeman Group aquifer on either side of the channel is consistent and should be considered as a secondary flow path. The Tertiary fluvial materials have been characterized as having higher clay content, generally lower permeability, and discontinuous sandstone beds (Golder, 1995a). However, GSM's experience in capturing groundwater below Tailings Impoundment No. 1 demonstrates that, once tailings impoundment seepage is introduced to the Bozeman Group aquifer, it moves readily and less predictably than in the alluvial channel sand and gravel deposits (Keats, 2001 and 2002).

Secondary groundwater flow paths from the pit are the principal faults and geologic structures in the bedrock aquifer, other than the Corridor Fault, which is considered a primary flow path. These structures and faults could provide conduits for groundwater transport (Figure 3-2). The principal features of concern are:

- The Range Front Fault east of the pit;
- The east-west trending Telluride Zone and connected Sunlight Fault to the north and Meteor Fault south of the pit;
- The Golden Sunlight Principal Deformation Zone (PDZ) south of the pit;
- The Sunlight Syncline south of the pit (likely the source of Stepan Spring);
- The Latite Valley PDZ southwest of the pit;
- The Fenner Fault, which contributes water to the pit at present but is not mapped outside of the pit;
- The Lone Eagle Fault and potentially connected unnamed faults extending west of the pit; and,
- The Saint Paul PDZ may be connected via mapped faults west of the pit.

As described in Section 3.2.1.5, the extensive ferricrete deposits and gold enrichment along and downgradient of the Range Front Fault suggest that groundwater transport of metalliferous fluids from the area of the pit has occurred in the past. The ferricrete appears to be evidence that discharge along the fault found its way into the Tertiary materials, where it joined the flow paths discussed above.

All the springs on the mine site associated with adits are on or associated with some type of geologic structure or mineralized area (Gallagher, 2003e). Springs are shown on Figure 3-5. Rattlesnake Spring lies on the northwest-trending Rattlesnake Fault. Its water chemistry contains ARD effects indicative of a hydrologic connection to mineralized zones in Bull Mountain. The Arkose Valley Spring is associated with the Latite Valley PDZ. Many small faults and structures surround Bunkhouse Springs and

North Borrow Springs, but these springs do not appear to be related to the faults. South of Bull Mountain, Stepan Spring lies directly over the Sunlight Syncline, suggesting a connection to this geologic structure. The Sunlight Syncline is mapped as a continuous feature from the pit area to Stepan Spring (GSM, 1996). The shape and structure of the syncline funnel ARD from mineralized zones in and south of the pit to Stepan Spring. The thick ferricrete deposits at the spring indicate that ARD transport and deposition have been a long-term occurrence at this location.

Some of the highest yielding wells at GSM lie on faults. PW-60, for example, produces an estimated 40 gpm and lies directly on the unnamed southwest extension of the Range Front Fault (Figure 3-2). PW-21, reported to yield up to 60 gpm, lies on the Latite Valley PDZ. Conversely, no high-yielding wells in the Proterozoic aquifer have been found away from mapped faults. Considering the limited number of monitoring wells installed along faults, and uncertainty of intersecting faults at depth, this apparent association of preferential permeability along faults and other types of geologic structures, although based on limited data, was considered important. Thus, mapped faults which may be traced to the pit area were considered as one of several factors in evaluating hydrologic connection to the pit.

A study of well and spring hydrographs from 1997 to 2003 indicated that the below average precipitation of the 4 to 5 years before the study has likely influenced groundwater levels in all aquifers monitored (HSI, 2003). This obscures any potential of observing indirect evidence of a hydrologic connection from fault-oriented springs and wells to the pit.

3.4 SOILS AND RECLAMATION

The 1997 Draft EIS, Section III.C described the soils within the permit area. Generally, the soils around the pit are on steep slopes and are rocky, shallow, and poorly developed. Soils are salvaged and stockpiled for reclamation purposes. There is a shortfall of stockpiled topsoil for the partial pit backfill alternatives. Additional soils, if needed, would be salvaged from the area permitted for the East Waste Rock Dump Complex and a borrow area north of Tailings Impoundment No. 2 (GSM, 2002). These soils are generally on less steep slopes and are less rocky, deeper, and more developed than the soils around the pit. In addition, a new soil borrow source has been identified north of Tailings Impoundment No. 1, which would require an additional 31 acres of disturbance to salvage enough soil for the pit backfill alternatives. Table 3-2 presents information on the suitability of soils that could be disturbed under the alternatives.

Table 3 - 2. Soil Suitability as Cover

GSM Site Area	Soil Suitability
Western Portion	Soil coarse fragment contents (gravel-, cobble-, and rock-sized geologic materials) are typically somewhat higher in the western portions of the project area. Coarse fragment content has a dual effect on the quality of soils for revegetation purposes. The higher the volume of coarse fragments (assuming the fragments do not readily weather to soil), the less the available water holding capacity of the soil for any given soil texture. For example, a loam soil containing no coarse fragments can store approximately 2.0 inches of water per foot of soil material. A loam soil containing 20 percent coarse fragments can store approximately 1.6 inches of water, while a loam soil containing 50 percent coarse fragments is capable of storing 1.1 inches of water. Conversely, angular coarse fragments occurring on the soil surface decrease the susceptibility of soil to erosion by providing an "armoring effect". The calcium carbonate content and pH buffering capacity of the dominant soils of this area are low.
Eastern Portion	With respect to overall soil characteristics and soil salvage potentials, the soils of this portion of the project area typically overlie less steep slopes, are deeper, have lower coarse fragment contents, and have higher pH values than the soils of the western portion of the project area. These soils have, in part, developed on limestone as well as calcareous loess and have a net buffering capacity due to the calcium carbonate content.

3.5 WILDLIFE

Wildlife resources are addressed in the 1997 Draft EIS, Section III.E. A summary of that information is presented below.

A variety of habitats utilized by resident and migratory wildlife species are found within the general vicinity of the GSM pit. The mule deer is the most common big game species in and around the existing mine site. Several bat species use abandoned mines for roost sites, including winter hibernacula. Bat surveys identified several *Myotis spp.* and big brown bats flying in the vicinity of the mine (GSM, 1995b). A fringed myotis was captured during the surveys and released. Five hibernating big brown bats were observed in one of the four abandoned mines surveyed.

In addition to the named species, long-legged myotis, Yuma myotis, long-eared myotis, and western small-footed myotis are found or may be found in the area (SRK Consulting, 2005).

Twelve raptor species were previously observed in the vicinity of the mine. These species include the bald eagle, golden eagle, turkey vulture, rough-legged hawk, red-tailed hawk, northern harrier, northern goshawk, sharp-shinned hawk, merlin, American kestrel, great-horned owl, and saw-whet owl. An active golden eagle nest was documented in 2003 north of the pit highwall (SRK Consulting, 2005 and Shannon Dunlap, pers. communication, 2006).

3.6 CULTURAL RESOURCES

Cultural resources are addressed in the 1997 Draft EIS, Section III.L.

Cultural resources consist of prehistoric and historic archaeological deposits; structures of historic or architectural importance; and traditional ceremonial, ethnographic, and burial sites. Cultural resources are nonrenewable resources, which are afforded protection by federal, state, and local laws, ordinances, and guidelines.

Several previous archaeological surveys have been conducted in the vicinity (Peterson and Mehls 1994). Reports detailing the results of intensive archaeological evaluations conducted in the GSM area are on file at the BLM Butte Field Office and at the SHPO office in Helena. The only cultural resource that might be affected by pit reclamation is a historic cabin near the north highwall. Should an alternative involving cast blasting be selected, there would be an adverse impact to this historic property, which would require mitigation.

3.7 SOCIOECONOMIC CONDITIONS

Area economy, employment, taxes and income were described in detail in the 1997 Draft EIS, Chapter III, Section III.J, pages 204 through 213. This section updates the data from 1997 to present.

3.7.1 Employment

In 1998, GSM employed 202 full-time personnel, 11 part-time personnel and 39 contractors. As of March, 2006, GSM employed 132 full-time personnel and 17 contractors (Shannon Dunlap, GSM, personal communication, 2006).

Jefferson County is a rural county, with culture and economy historically dependent upon the land. Early economic activities were related to the extraction and utilization of natural resources. The mineral wealth found in the mountains and valleys of western Montana stimulated the county's initial growth. Other activities such as timbering, grazing, and agriculture followed. Natural resource and service industry activities dominate the economy and culture (U.S. Census Bureau, 2000, www.census.com).

The mining sector provides significant contributions to employment in Jefferson County. GSM provided 160 jobs in 2003 accounting for approximately 4.3 percent of total

covered employment. Secondary employment, primarily in the services sector, also is supported in the community by mining jobs at GSM. Table 3-3 shows employment information for Jefferson County and the State of Montana since the 1997 Draft EIS.

Table 3 - 3. Jefferson County and State of Montana Employment and Income

	Jefferson County		**Montana**	
Population (2001)	10,405		904,433	
Labor Force (2000)	5,183		458,306	
Unemployment Rate (2001)	3.5%		4.1%	
Per Capita Income (1991)	$18,250		$17,151	
Median Household Income (1999)	$41,506		$33,024	
Employment Sector (2000)	**Number Employed**	**Percent of Employment**	**Number Employed**	**Percent of Employment**
Ag/Forestry/Fishing & Hunting/Mining	410	8.4	33,691	7.9
Construction	411	8.4	31,724	7.4
Manufacturing	186	3.8	25,414	6.0
Transportation and Warehousing and Utilities	236	4.8	23,109	5.4
Wholesale Trade	120	2.5	12,937	3.0
Retail Trade	424	8.7	54,468	12.8
Finance/Ins/Real Estate	320	6.5	23,351	5.5
Services	2,034	41.6	195,988	46.1
Public Administration	754	15.4	25,295	5.9
Total, All Industries	**4,895**	**100**	**425,977**	**100**

Note: Source U.S. Census Bureau, 2000, www.census.gov
Note: Services Industry includes professional, scientific, management, administrative and waste management services; educational, health and social services; arts, entertainment, recreation, accommodation and food services; "other services" (except public administration); and information.

3.7.2 Tax Revenues

Table 3-4 provides the specific GSM economic contribution to the State of Montana. Since it began production in 1982, GSM has paid taxes to the state, county, and local communities in the form of the metals mine license tax, the gross proceeds tax, and other taxes. GSM's taxing district includes Whitehall High School and Cardwell Elementary.

Table 3 - 4. Economic Contributions of GSM

	1985	1990	1995	2000	2002	Total Since 1983
Gold Ounces Produced	**96,491**	**97,058**	**89,799**	**212,266**	**111,806**	**2,302,549**
Number of Employees	**146**	**259**	**301**	**92**	**83**	**193 (avg)**
Total Gross Payroll, Payroll Taxes, and Employee Benefits Paid	**$5,872,556**	**$11,934,434**	**$15,157,626**	**$7,679,237**	**$6,296,899**	**$205,977,606**
Total Property Taxes, Gross Proceeds Tax, and Metal Mines License Tax Paid	**$838,632**	**$1,645,634**	**$1,229,379**	**$1,873,003**	**$1,623,460**	**$28,441,051**
Total Purchases	**n/a**	**n/a**	**$35,007,164**	**$21,232,000**	**$27,354,151**	**$337,226,454***
Total Employee Taxes	**$355,098**	**$722,281**	**$3,028,753**	**$1,649,999**	**$1,048,225**	**$32,416,552**
* - Since 1991 only Source – GSM, personal communication, 2003						

The latest Jefferson County and State of Montana revenue figures for fiscal year 1998 and 2002 are shown in Table 3-5. County tax revenues are confined primarily to the property tax, which is assessed based on the total taxable value for the county and the consolidated mill levy (Jefferson County, personal communication, January 6, 2004).

Table 3 - 5. Jefferson County and State of Montana Revenues

Revenue Category	**1998**		**2002**		**2002 Percent GSM of Total**
	GSM	Total County	GSM	Total County	
Property Tax	$551,062	$8,468,801	$309,232	$8,131,529	3.8%
Gross Proceeds Tax	$389,771		$492,362		
Metal Mines License Tax	$847,243		$821,866		

3.8 LAND USE AND ACCESS

Land Use and Access is addressed in the 1997 Draft EIS, Section III.H. A summary of that information is presented below. Today, the primary land uses in the pit area are wildlife habitat and mineral extraction.

The majority of surface land in the current GSM permit area is owned by GSM. The remaining surface lands consist primarily of BLM-administered tracts, with DNRC-administered school trust land in Sections 16 (T2N, R3W) and 36 (T2N, R4W) (Figure 1-3).

The county's current mining operations provide employment and economic benefits for Jefferson County. The county recognizes that mining is a finite activity and it acknowledges the importance of expanding and diversifying the economic base. The Jefferson County Comprehensive Plan also emphasizes the value of "quality of life" issues and preserving environmental and cultural resources (Jefferson County, 1993).

The Jefferson County Comprehensive Plan Map depicts the area around the mine as a "Basic Resource with Development Constraints," meaning that the land is to be protected for agriculture, timber, and mineral resource utilization. Lands with this designation may have development and use constraints including any of the following: public ownership, steep slope, flood susceptibility, poor access, lack of potable water supply, and/or fire suppression capability (Jefferson County, 1993).

GSM applied for a minor revision in December 2003 to leave the mill complex for post mine industrial use by Jefferson County. This change in land use was approved in 2004 and modified in 2005 in Minor Revision 05-005.

3.9 AESTHETIC RESOURCES

Aesthetic resources are addressed in the 1997 Draft EIS, Chapter III, Section III.I.

The BLM Visual Resource Management (VRM) system is designed to help manage the quality of the landscape by minimizing impacts to visual resources resulting from development activities, while maintaining the effectiveness of all BLM resource programs. Through the visual analysis process outlined in BLM Handbook 8410-1, Visual Resource Inventory, rating categories are assigned. The categories describe the relative value by analyzing three components - scenic quality, viewer sensitivity, and distance zone - to provide an assessment of the current visual resources. VRM Classes I to IV are then assigned for the area, with management objectives ranging from maintaining minimal visual disturbance to allowing activities that entail major landscape modifications. The BLM, to date, has not assigned a VRM Classification for the lands around GSM, although the area has generally been managed as a potential VRM Class IV area because of the existing mining disturbances.

A Visual Resource Inventory (VRI) was conducted for the 1997 Draft EIS and is discussed there in Chapter III, Section III.1. The results of the VRI yielded a Class III rating. The study area was defined as the ridgeline encompassing present mining activity and surrounding BLM lands and parts of the surrounding valleys. A Class III rating provides for moderate changes to the existing landscape and activities that may attract the attention, but not dominate the view of the casual observer. Under a Class III rating, areas that currently do not conform to the management objectives would be designated as "Rehabilitation Areas"; these areas would be rehabilitated upon project completion to restore the natural characteristics of the landscape to the extent required for a Class III visual resource rating.

GSM has reclaimed 7 acres in the pit to date. GSM has planted tree seedlings along the upper pit highwall on the west and south sides of the pit. GSM has placed soil on the oxidized upper northwest corner of the pit to determine if revegetation can be successful with a small amount of soil placement.

3.10 SAFETY

Safety is an important issue at Barrick's Golden Sunlight Mine. Safety and Health education and training are key components to Golden Sunlight Mine's safety program.

In January of 2006, Barrick Gold acquired Placer Dome. Barrick's vision and philosophy are as follows:

Barrick's Vision:" *Every person going home safe and healthy every day."*

Barrick's Philosophy: We are committed to performing every job in a safe and healthy manner. Work-related injury or illness is unacceptable and we are committed to the identification, elimination or control of workplace hazards for the protection of ourselves and others. Everyone is responsible for workplace safety. *No job is ever worth doing in an unsafe way. None!*

Barrick's safety and health plan is a dynamic program requiring continuous improvement. The following are the elements of the program:

Core values:

- BEHAVE LIKE AN OWNER
- ACT WITH A SENSE OF URGENCY
- BE A TEAM PLAYER
- CONTINUALLY IMPROVE
- DELIVER RESULTS

Objectives and Strategies:

- Safety Leadership is a Line Management Responsibility;
- Increased Ownership and Participation of "Everyone" – all stakeholders - for Safety and Health;
- Continue to build an incident-free safety and health culture;
- Continuously improve the safety and health programs, systems and resources utilizing "best of industry" practices;
- Develop programs and processes in support of health and wellness.

Priorities for 2007 and 2008:

2007

Continued focus on:

- Leadership and Personal Commitment
- Risk Management
- Contractor Controls
- Health and Wellness

2008

- Training and Competence
- Incident Investigation
- Operational Controls and Procedures

In safety reporting, medical aid injuries are defined as occupational work-related injuries that require medical treatment exceeding a first aid category but do not result in lost time. Lost time injuries are defined as work-related incidents that cause a worker to miss the next regular scheduled shift from work. All injury statistics are reported relative to these definitions.

As of January 1, 2007, GSM employees and contractors had worked 515,665 hours without a lost time accident (LTA). GSM's non-fatal days lost rate for 2006 was 0 compared to a MSHA national average of 1.63.